1208 LPD

Low-Power Design for 16-bit Devices

Objectives

- **When you finish this class you will know:**
  - What low-power features are available on 16-bit PIC® MCUs
  - Design best practices for low-power applications
  - Power Consumption of PIC24F MCUs

Agenda

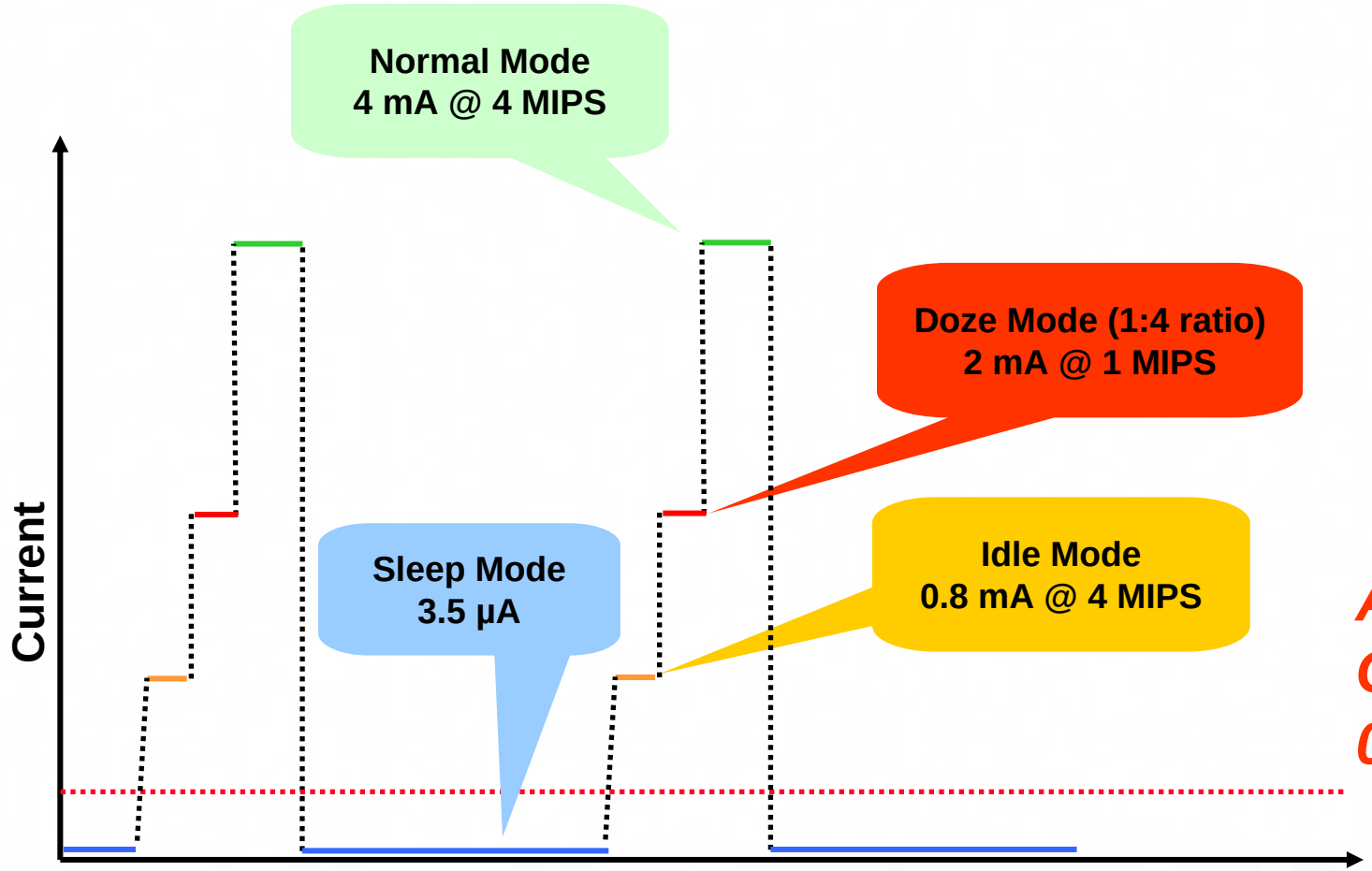
- Power-Saving Feature Overview
- Peripheral Power Consumption and Power Reduction Tips
- Other Power Reduction Tips
- Power Reduction Demo
- Case Study – Benchmark Data
- Summary

Power-Saving Features

Power-Saving Features

- **Sleep, Idle, and Doze Modes**
- **Clock Switching**
- **Peripheral Module Disable (PMD) Bits**
- **Selectable Secondary Oscillator**
  - Higher Gain or Lower Power
- **Deep Sleep Mode**

Power-Saving Modes



Average Current 0.25 mA

Power-Saving Modes

	Deep Sleep	Sleep
Power	<1 uA-1 uA	3.5 uA
Peripherals	INT1, DSWDT & RTCC	RTCC, INTx, WDT, ADC, Timer 1 and Comparators
RAM Retention	All Reset	All Retained
SFR Retention	I/O States, RTCC and DSSEMAx Only	All Retained
Wake-up	POR, MCLR, INT1, DSWDT, and RTCC	Many Options

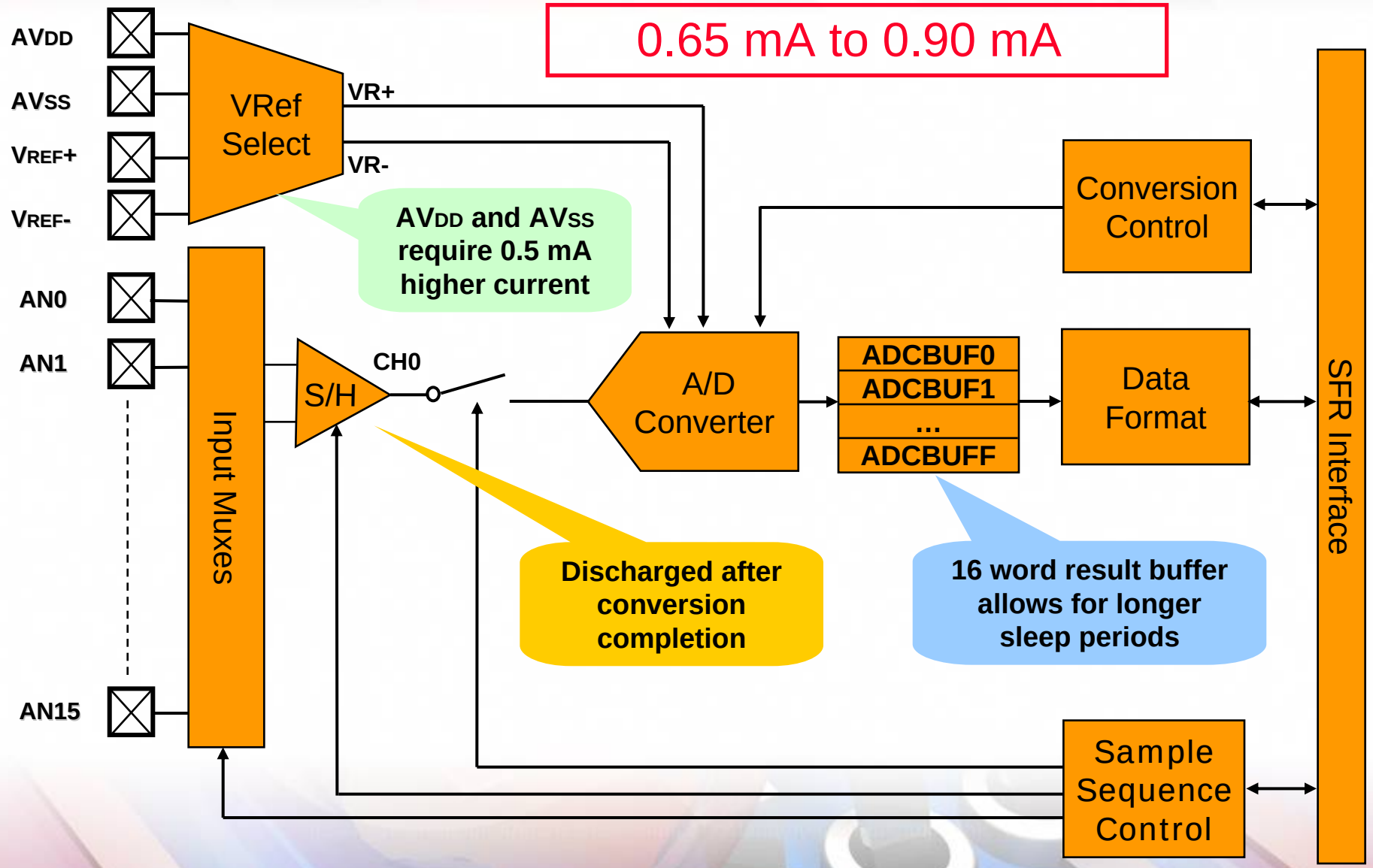
Peripheral Power Consumption and Power Reduction Tips

Peripheral Power Consumption

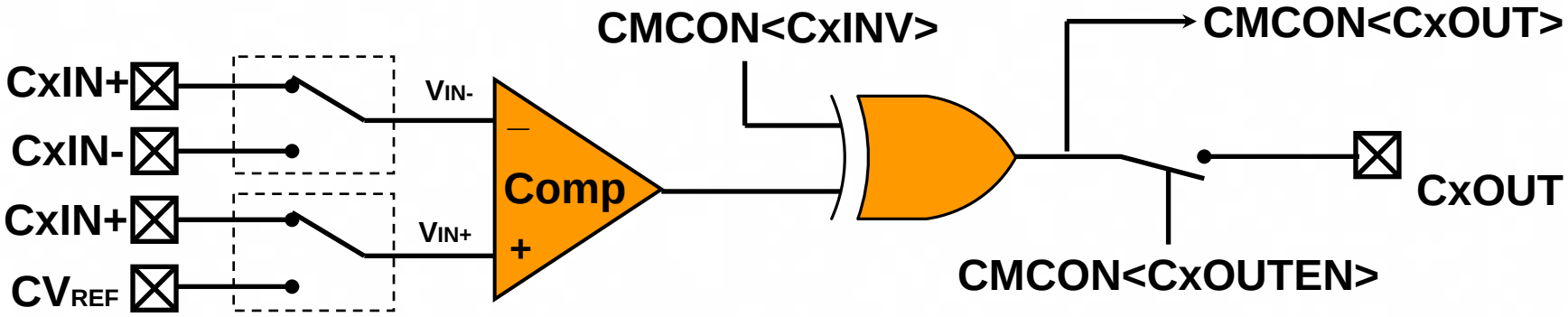
- ADC and Comparators
- Serial Communication
- Flash Modification
- RTCC and Timers

Analog Peripherals

ADC Power Consumption



Comparator Power Consumption



- **20 uA Base Current**
  - Input level variation adds ~20 uA
  - High frequency adds ~20 uA-100 uA
  - Enabling output adds 0 uA to 0.5 mA
- **Comparator Voltage Reference**
  - 65 uA Typical

Analog Peripheral Tips

- **Choose external references ($V_{REF+/-}$ and CxIN+/-) over internal references (AV_{DD}/AV_{SS} and CV_{REF})**
- **Fast sample and disable ADC**
  - 50% less ADC power (0.7 mA typ)
- **Utilize 16 word deep buffer for Sleep mode conversions**

Serial Communication Peripherals

Serial Communications Power Consumption

- **Enabling module adds no current**
- **Faster speeds more current**
- **UART**
  - Lowest power serial
  - Baud has minimal effect

Constant TX/RX	
4 MIPS	200 uA
16 MIPS	300 uA

I²C™ Power Consumption

- **Module current**
  - 50-200 uA – based on speed
- **System current**
  - Dependent on pull-up value and data sent

$3.3\,V \div 4.7\,k\Omega = 0.7\,mA$

$0.7\,mA * 2 \text{ lines} = 1.4\,mA$

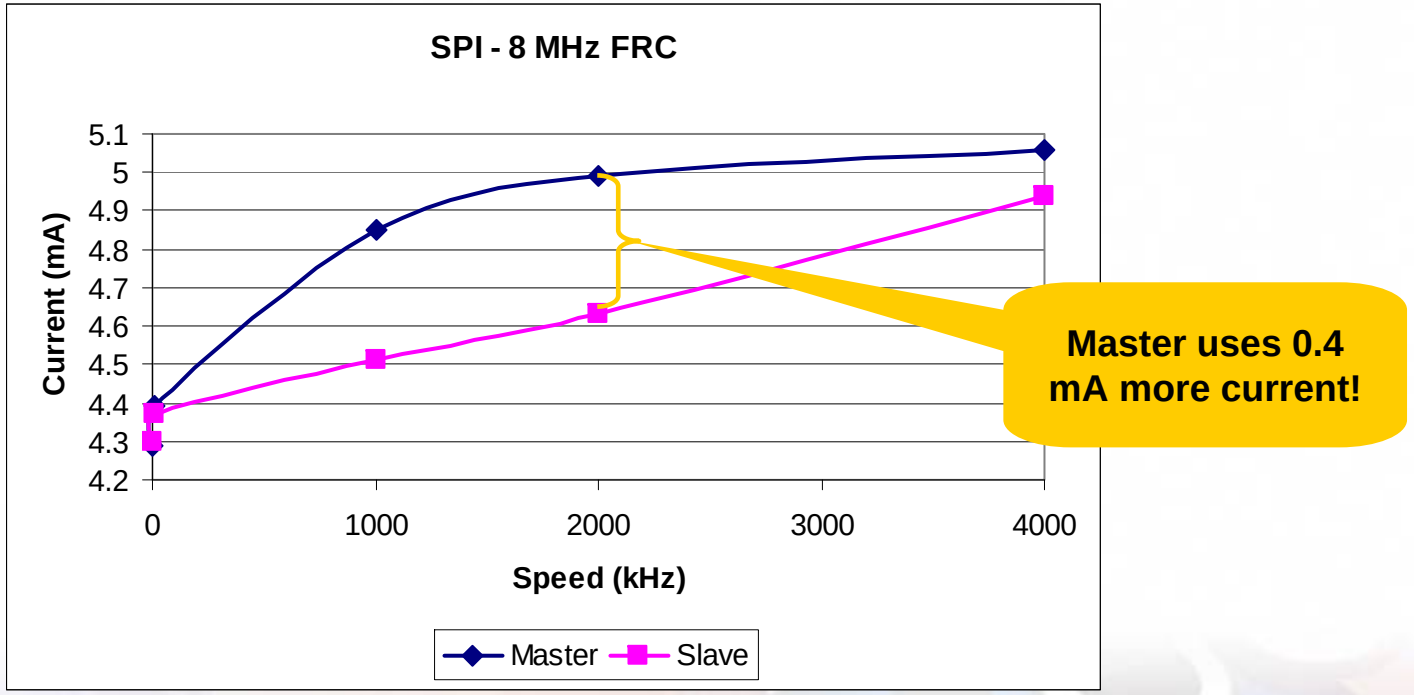
$\text{Typical Data} = 50\% \text{ active}$

$1.4\,mA * 50\% = 0.7\,mA$

1 MHz I²C, 4.7k pull-ups	
Module	0.2 mA
System	0.7 mA
Total	~0.9 mA

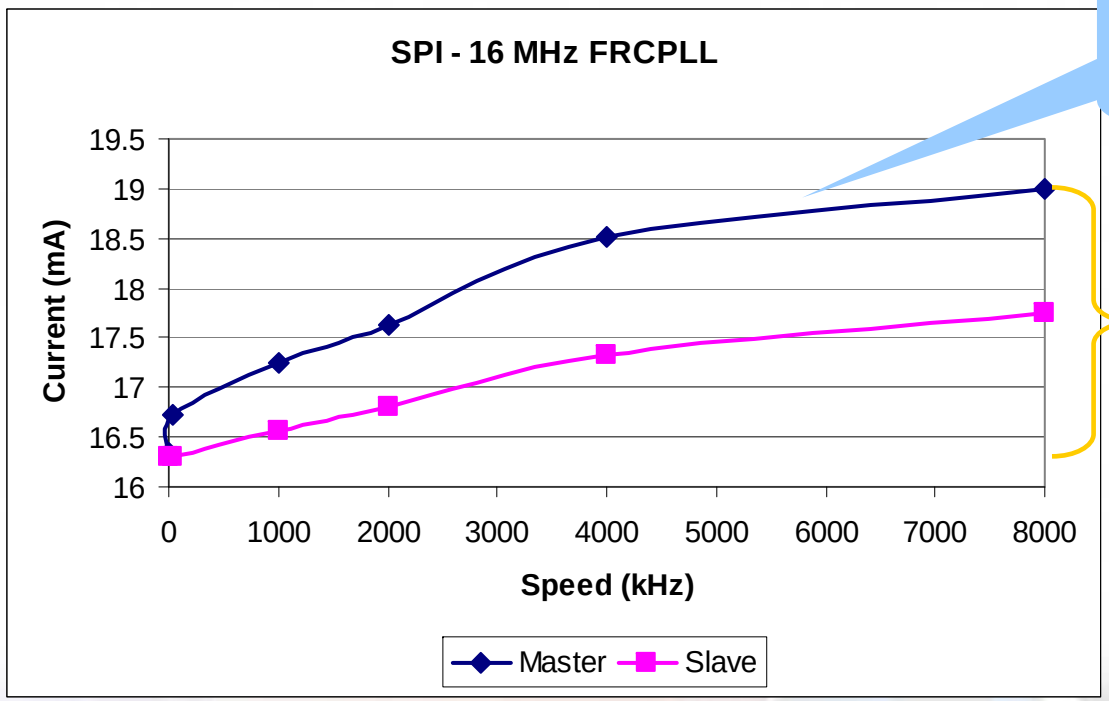
SPI Power Consumption

- Highest power serial protocol
- Slave is lower power



SPI Power Consumption

- **Power vs. Speed is non linear – utilize to save average power**



Not Linear: 2x speed is only 20% more current!

2.65 mA to run 8 MHz SPI

Serial Communications Peripheral Tips

- **Fast infrequent transmissions instead of slow constant transmissions**
- **I²C™**
  - Use larger resistors for pull ups

Transmit 1's instead of 0's!

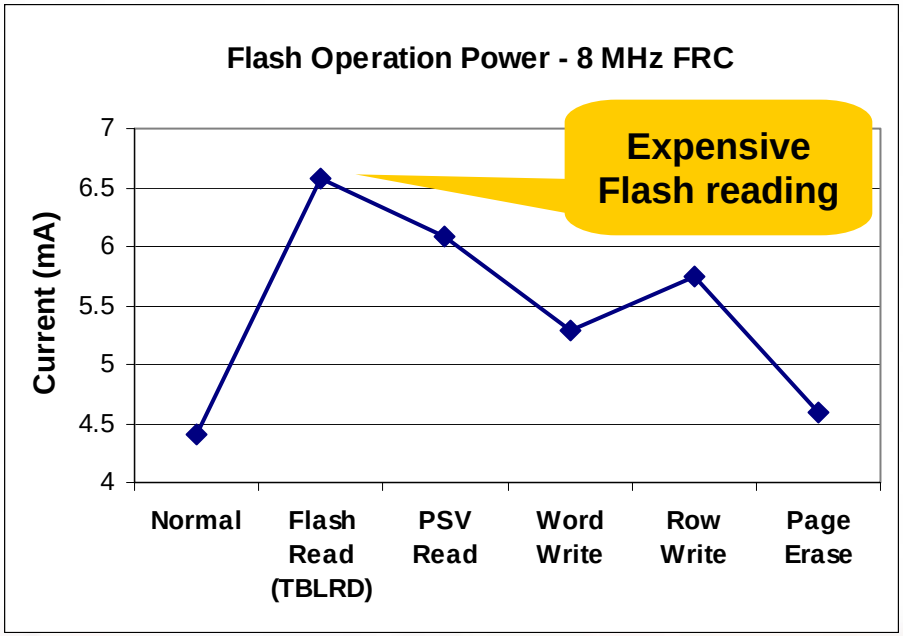
Serial Communications Peripheral Tips

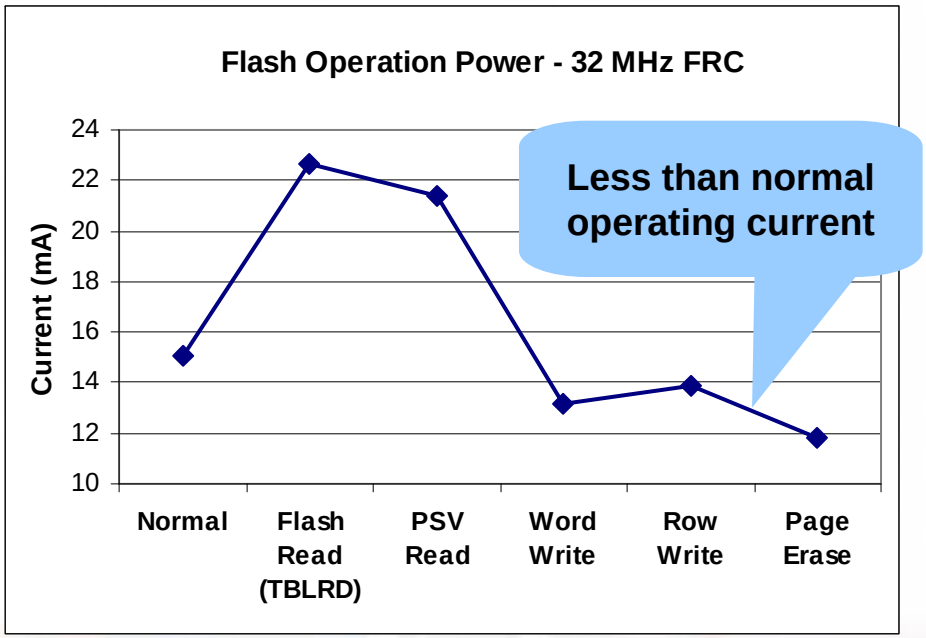
- **SPI**
  - Master uses more current than slave
  - Don’t constantly transmit at high speeds
  - Low-impedance I/O
    - **3 high-speed lines!**

Flash Operations

Flash Operations Power Consumption

- Flash reads are high power
- Flash changes suspend CPU and enable FRC





Timing Peripherals

RTCC Power Consumption

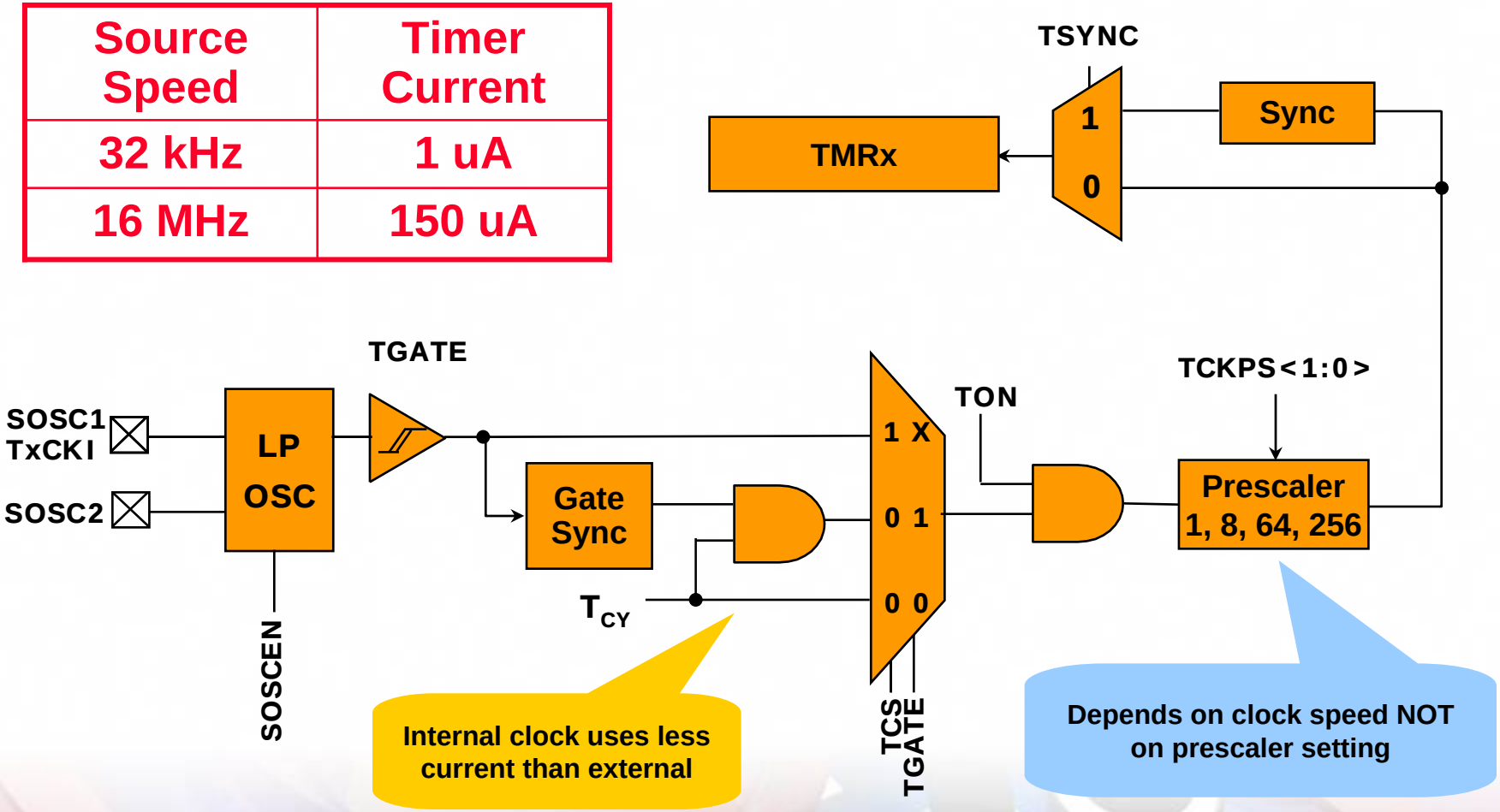
- **SOSC current determines power requirements**

Sleep w/o RTCC	**4 uA**
Sleep w/ RTCC	**7.5 uA**

- **Negligible for dynamic power**

Timer Power Consumption

Source Speed	Timer Current
32 kHz	1 uA
16 MHz	150 uA



Other Power Reduction Tips

Tips and Tricks

- **Hardware tips**
  - Voltage regulators
  - Circuit design and I/O best practices
- **Firmware tips**
  - Clock speed best practices

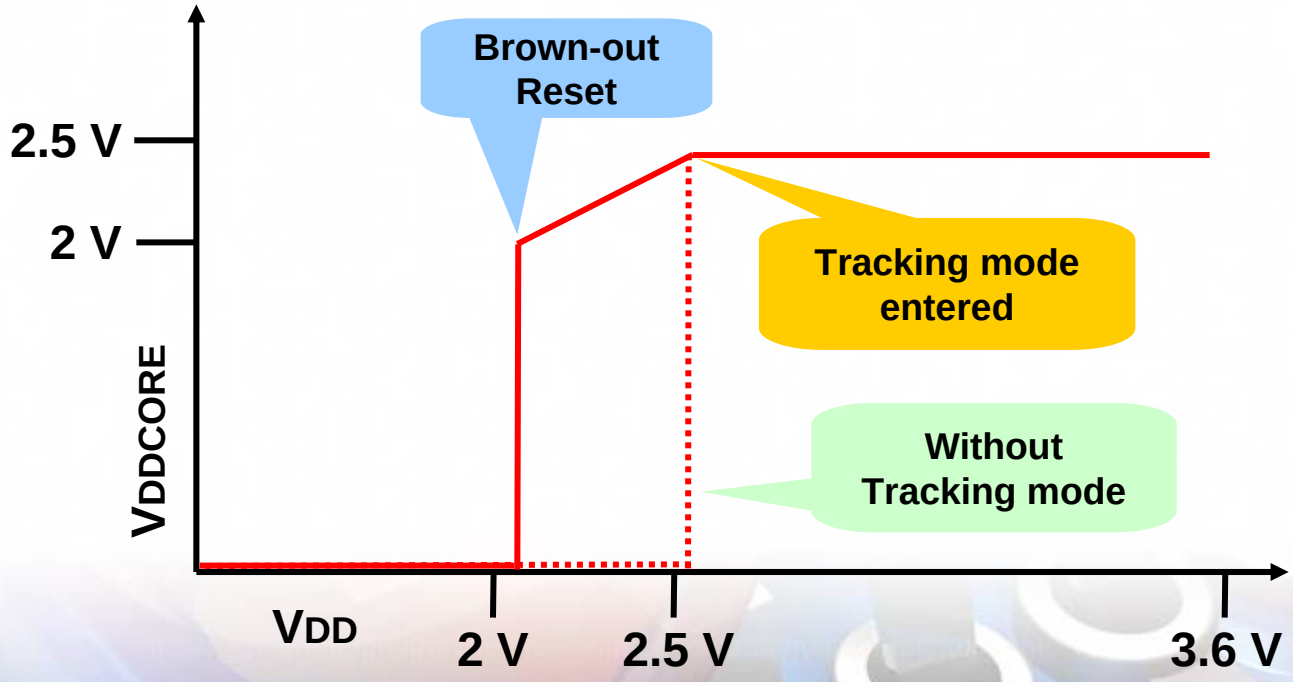
Hardware Tips
Internal Regulator

- **Suspend mode**
  - Regulator removes power from Flash to decrease I_{PD}
  - VREGS (RCON<8>)

3.3V & 25°C	I_{PD}	Wake-up
Disabled	45 µA	10 µS
Enabled	5 µA	190 µS / 10 µS

Hardware Tips
Internal Regulator

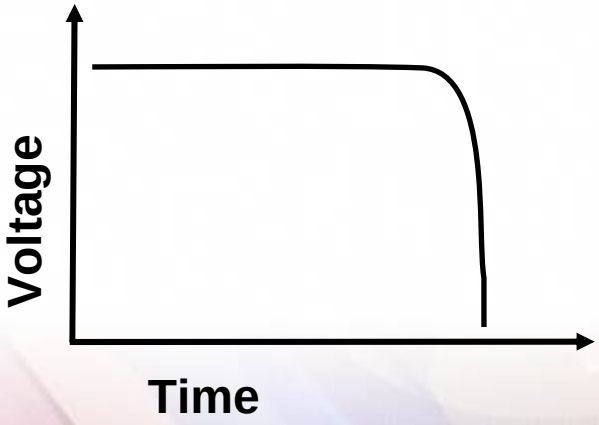
- **Tracking mode**
  - Regulator output follows VDD input when below LVD levels

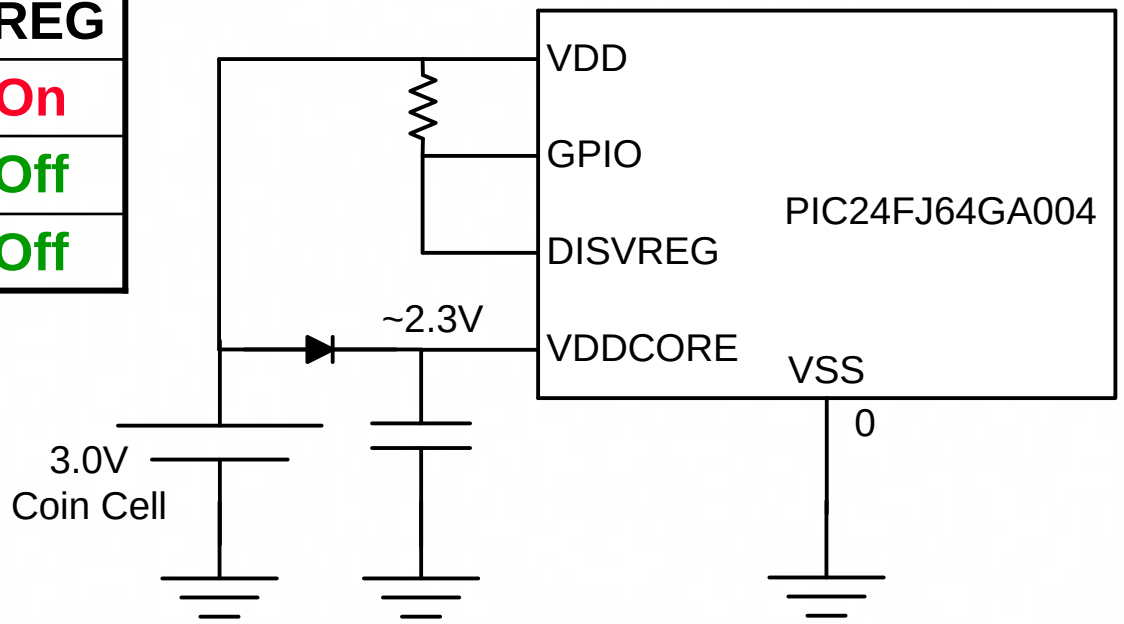


Hardware Tips
Regulator Disabled

- **Maximum Power Savings with 3V Coin Cell**

VDD	VDDCORE	IPD	VREG
3.3V	2.5V	3.5 uA	On
3.3V	2.5V	0.3 uA	Off
3.3V	2.0V	0.2 uA	Off

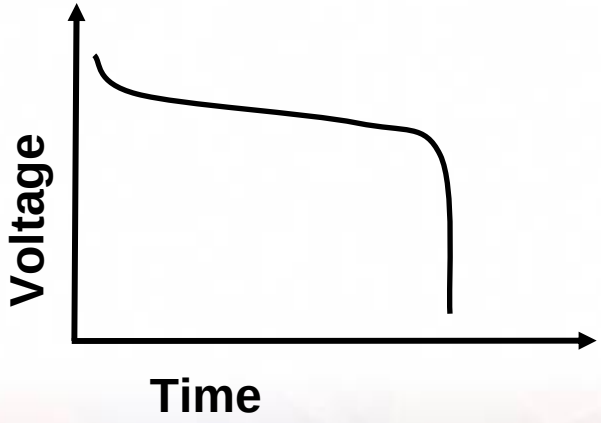


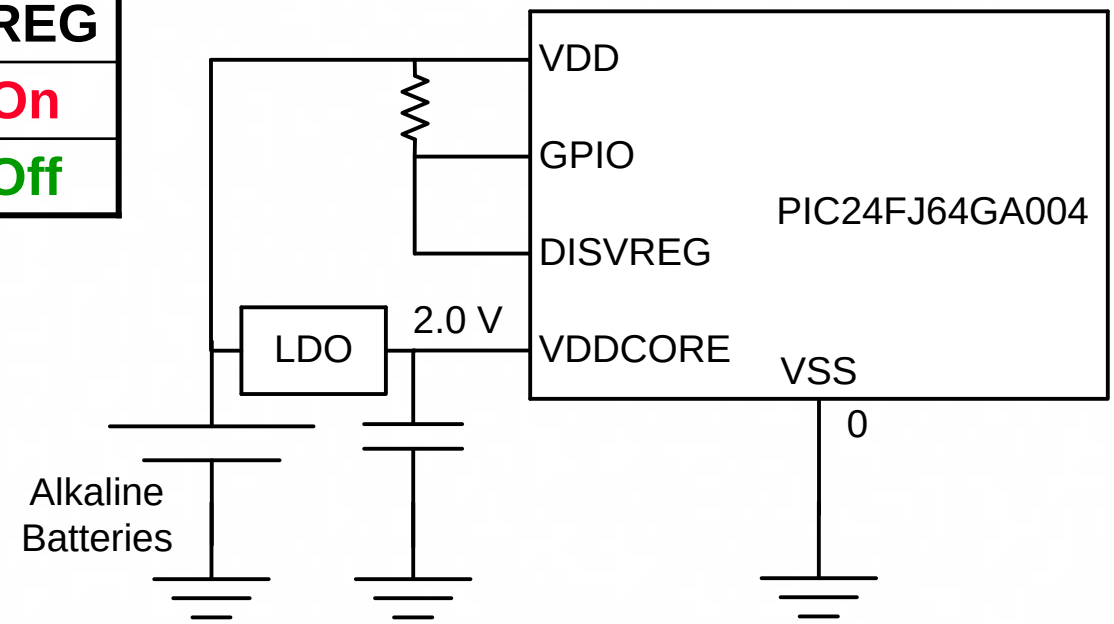


Hardware Tips
Regulator Disabled

- **Maximum Power Savings with AA batteries**

VDD	VDDCORE	IDD	VREG
3.3V	2.5V	3.6 mA	On
3.3V	2.0V	2.2 mA	Off





Hardware Tips – I/O

Floating Pin Table of Pain	Bad Case	Worst Case
1 Floating Pin	35 uA	0.5 mA
2 Floating Pins	65 uA	1 mA
10 Floating Pins	305 uA	5 mA

- **No floating input pins**
  - Drive unused GPIO as outputs
  - Pull up or pull down
- **Keep impedances low**

Firmware Tips – General

- **Turn off unnecessary modules before entering Sleep**
  - Important for modules which may remain active in sleep mode
- **Utilize Idle and Doze mode any time operation is non-critical**
  - Idle Mode – 80% less power
  - Doze Mode – 35-70% less power

Firmware Tips – General

- **RAM and SFR accesses require more power than NOPs**
  - Insert NOPs into non-critical sections to reduce average power

High Power: 19.1 mA

```
while(!_T1IF) i++;
```

Low Power: 16.4 mA

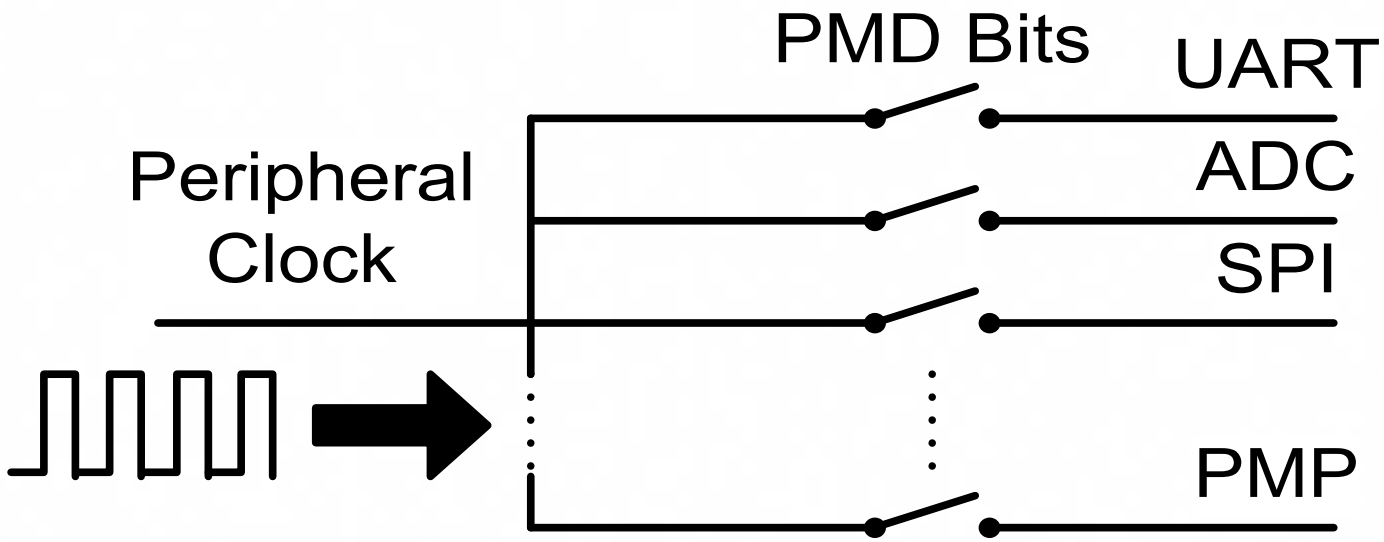
```
while(!_T1IF){
      i++;
      Nop();
      Nop();
      Nop();
      Nop();
      Nop();
}
```

Firmware Tips – Clocks

- **Clock Switching**
  - Use 32 kHz LPRC, SOSC, or FRCDIV for non-critical sections
- **Running 8 MHz FRC Uses 350 uA to 450 uA**
- **Timers**
  - Use internal timer if possible – external requires more current

Firmware Tips – Clocks

- **Utilize PMD at High Speed**

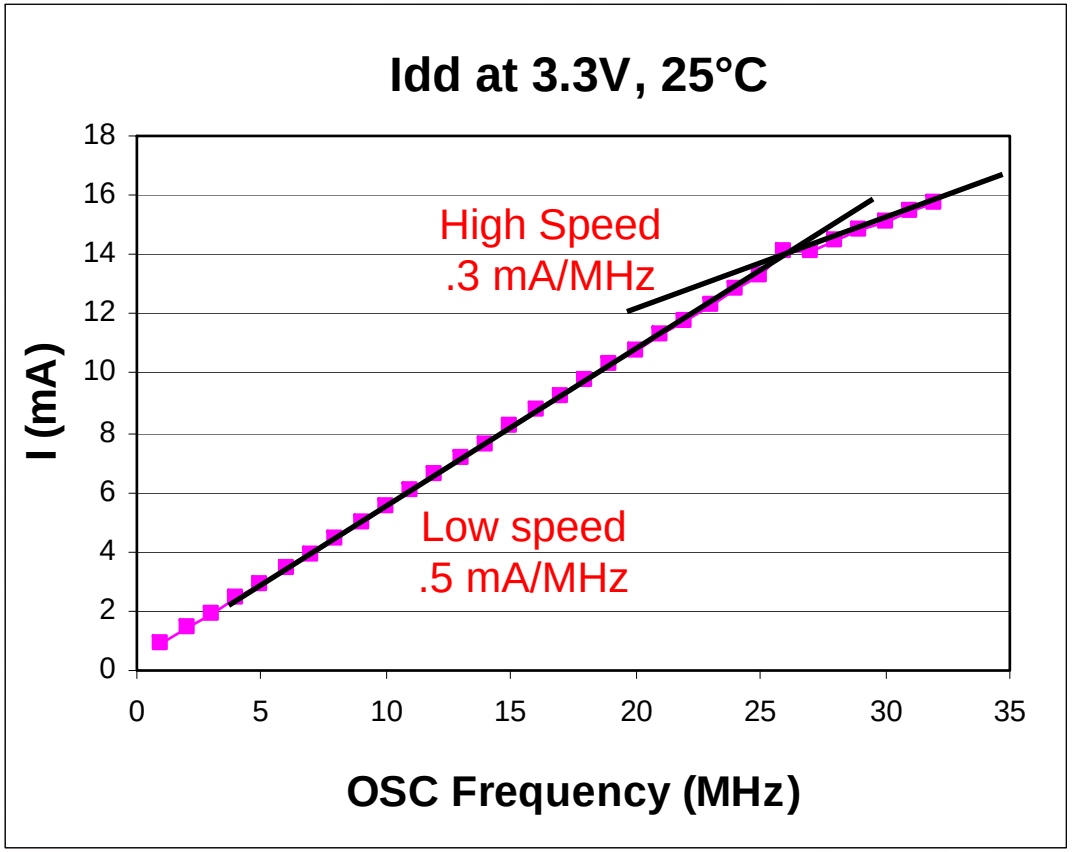


Firmware Tips – Clocks

- Run faster
- 32 MHz + Sleep

  vs.

  8 MHz constant
- Higher speeds are more efficient



Peripheral Power Summary

Dynamic Power	I_{DD} Impact
CPU (8 MHz)	3.8 mA
ADC	1.0 mA
UART	0.2 mA
SPI (4 MHz)	0.7 mA
I^2C^{TM} (System)	1.0 mA
Flash Read	2.1 mA

Watch out for these!

Static Power	I_{PD} Impact
Base	3.5 uA
ADC	785.0 uA
Comparator	20.0 uA
RTCC (+SOSC)	4.0 uA
Timer (31 kHz)	1.0 uA
WDT	3.0 uA

Demo of Tips Described

Case Study
Benchmark Data

Summary

- **Today We Covered:**
  - 16-bit Power-Saving Features
  - Peripheral Power Consumption Data
  - Power Reduction Techniques
  - Case Study – Power Comparison and Benchmark Data

Development Tools

- **Explorer 16 with PIC24FJ256GA110 PIM**
- **Graphics PICtail™ Plus Daughter Board**

Additional Resources

- **Data Sheets**
  - PIC24FJ64GA004 Data Sheet (DS39881)
  - PIC24FJ256GA110 Data Sheet (DS39905)
- **MASTERs/RTC Classes**
  - 1206 GSS (MASTERs)
  - 203 PRC and 204 ADV (RTCs)

Questions?

Trademarks